David Henderson, Dr. Shelly Miller, Dr Jana Milford
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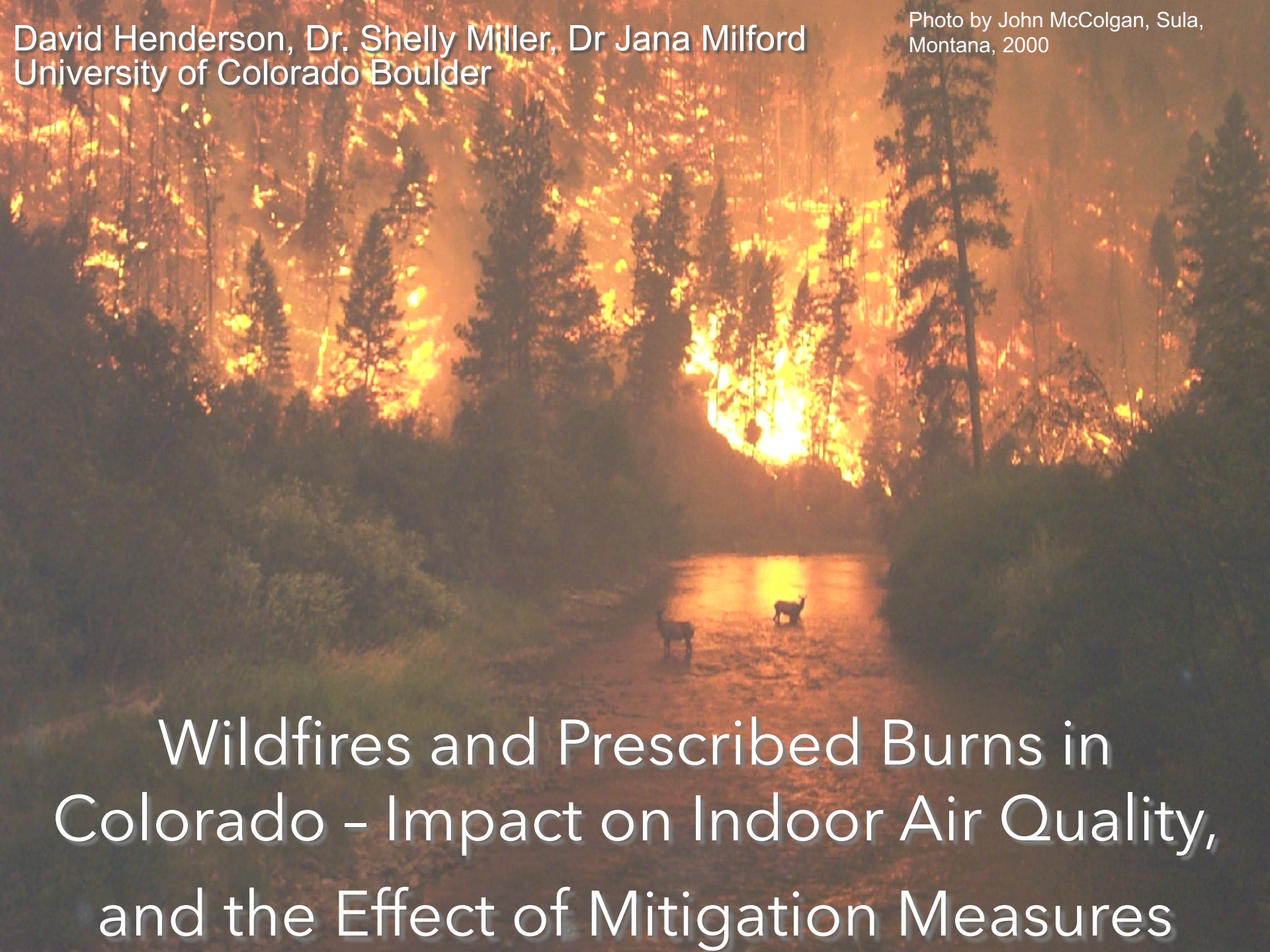


Photo by John McColgan, Sula, Montana, 2000

Wildfires and Prescribed Burns in Colorado – Impact on Indoor Air Quality, and the Effect of Mitigation Measures

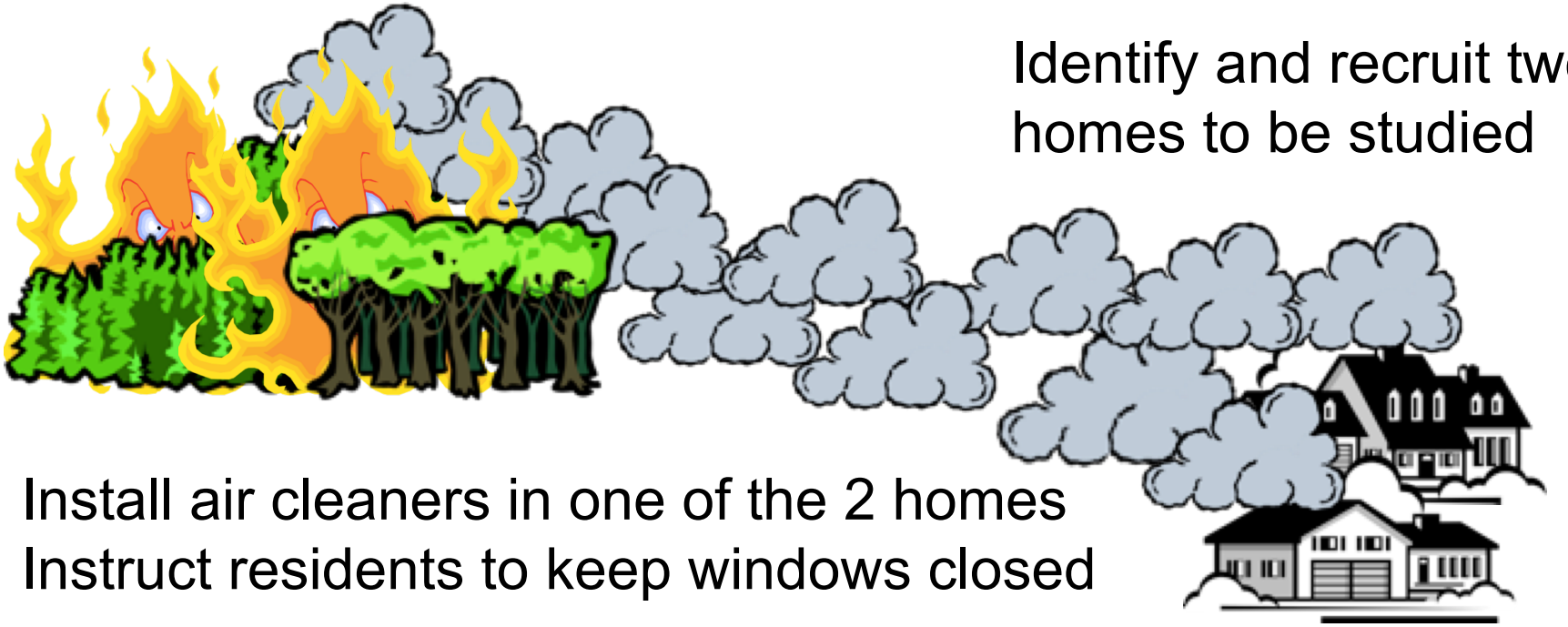
Research Objectives

- Measure residential indoor and outdoor $PM_{2.5}$ while wildfire smoke is present

- Determine the effectiveness of recommended indoor exposure mitigation measures
  - Keeping windows closed
  - Using portable air cleaners

Experimental Design

Locate wildfire producing smoke
that will impact local residents



Identify and recruit two
homes to be studied

Install air cleaners in one of the 2 homes
Instruct residents to keep windows closed

Homes of similar age and construction

Monitor indoor and outdoor $PM_{2.5}$
concentrations at both homes during fire

$PM_{2.5}$ mass concentrations using Harvard impactors

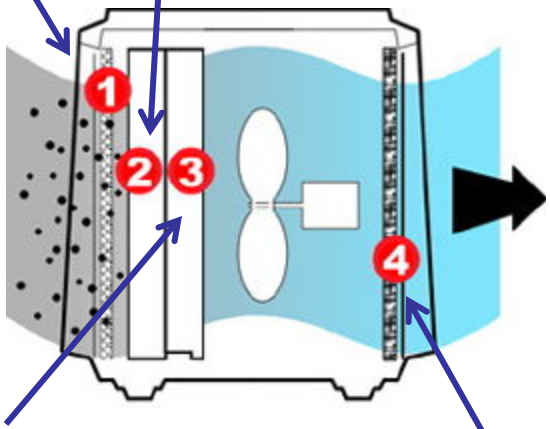
particle # concentrations <0.5 μm using Climet optical particle counters

Air-exchange rate using CO_2 tracer gas decay

Air Cleaners

Friedrich C-90a
Electrostatic Precipitator

- PRE-FILTER catches larger particles
- IONIZING CELL electrically charges particles when they pass through a powerful electric field



- COLLECTOR PLATES immediately attract "charged" particles
- ACTIVATED CARBON FILTER removes most common odors and fumes

- 3 tests performed on the air cleaners in a test chamber to measure Clean Air Delivery Rate (CADR)
- We measured an average CADR of 420 m^3/h
- Agrees with CADR of 325-370 m^3/h that is published by Association of Home Appliance Manufacturers

Quantifying air cleaner performance

1. Effectiveness

2. CADR

Effectiveness, E

- Quantifies improvement in indoor air quality that is associated with the technology's use

Particle concentration with no air cleaner in use

Particle concentration with an air cleaner in use

$$E = \frac{C_{ref} - C_{AC}}{C_{ref}}$$

E can range between 0 and 1

E = 1 represents ideal performance

E = 0 indicates complete lack of improvement

Clean air delivery rate

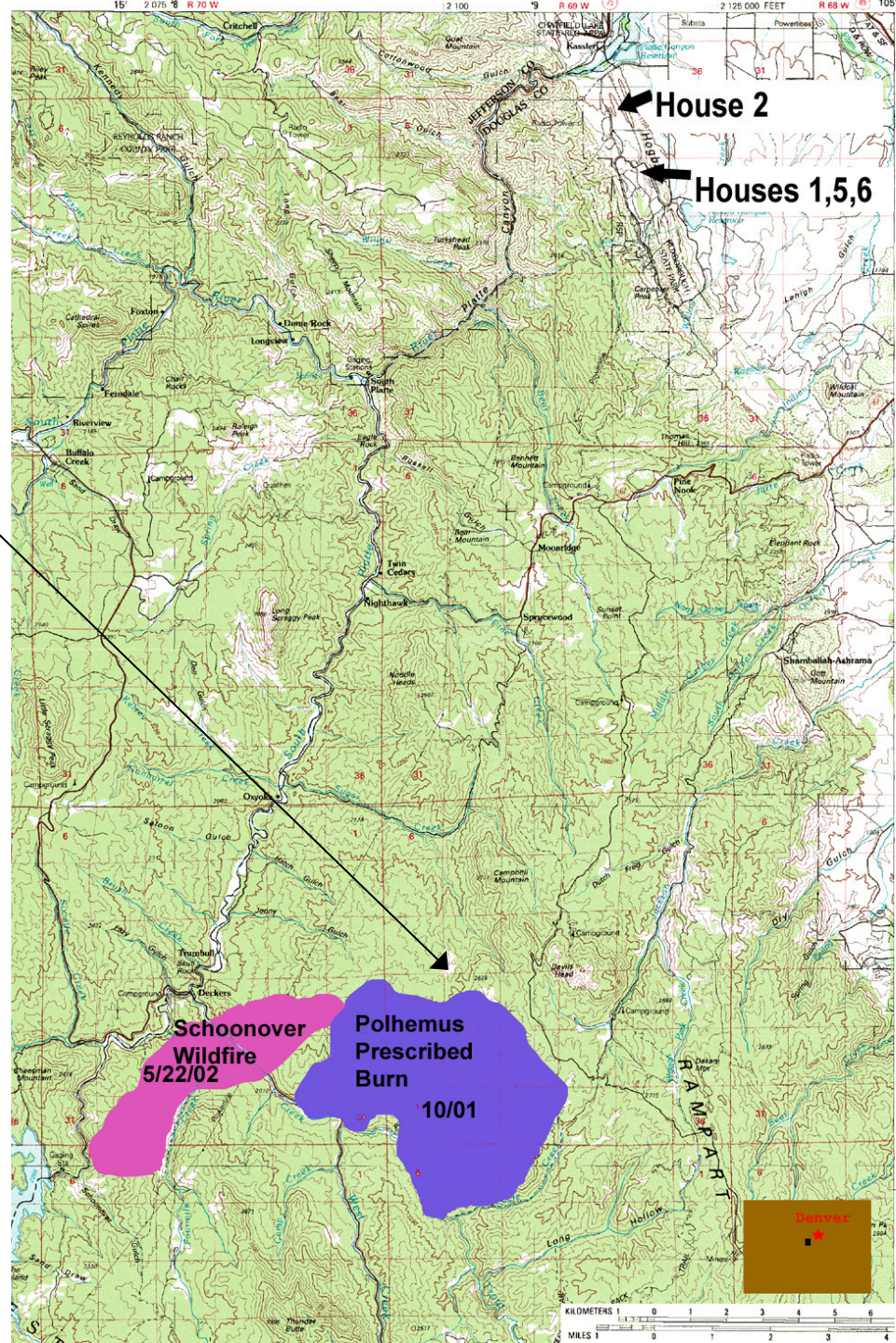
- single-pass efficiency of the device (fractional removal of pollutants from the air stream as it passes through the device) multiplied by the airflow rate through the device (Nazaroff, 2000)
- airflow rate that represents the effective amount of particle-clean air produced by the air cleaner (Offermann et al., 1985)

Clean air delivery rate

- The Association of Home Appliance Manufacturers (AHAM) has published method ANSI/AHAM AC-1-2002, which determines the CADR for three types of particulate matter—dust, tobacco smoke, and pollen (AHAM, 2002).

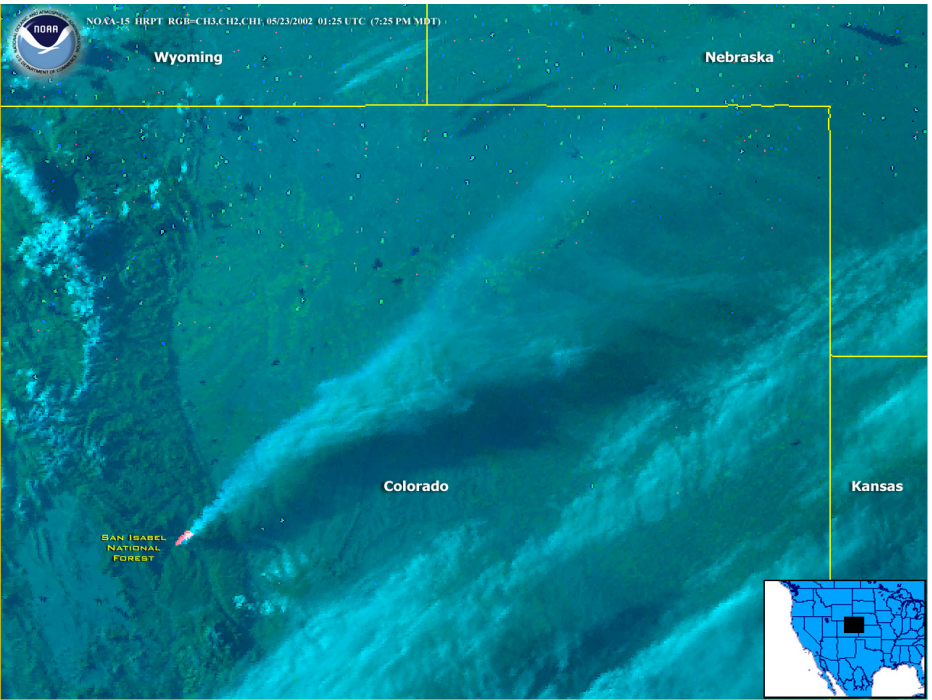
Polhemus prescribed burn

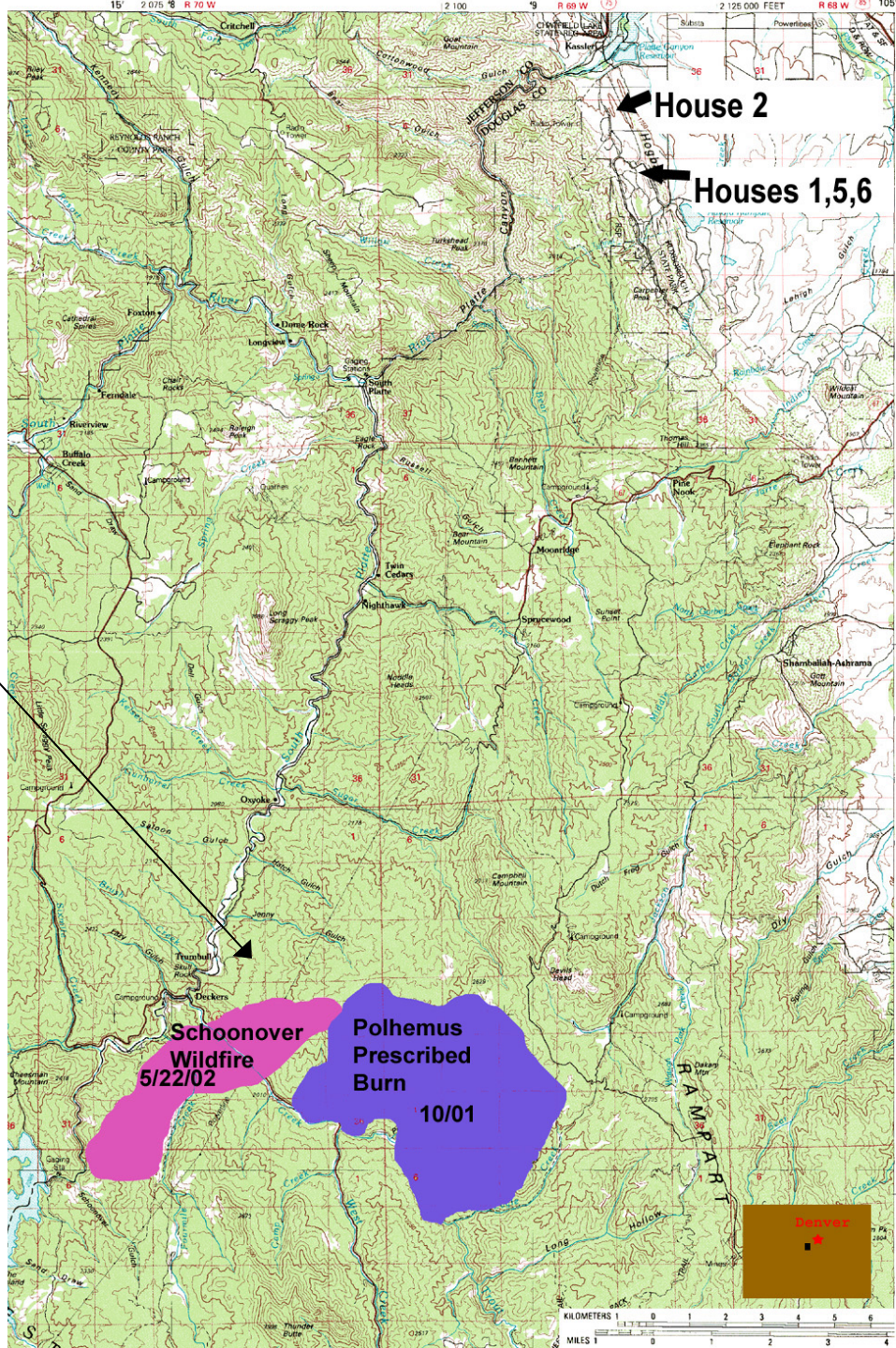
Burned all October 2001, producing heavy smoke on several days. Monitoring took place 10/20/01 to 10/21/01 when 2500 acres were ignited. Houses 1 and 2 were located 24 and 27 km north of this fire



Schonover wildfire

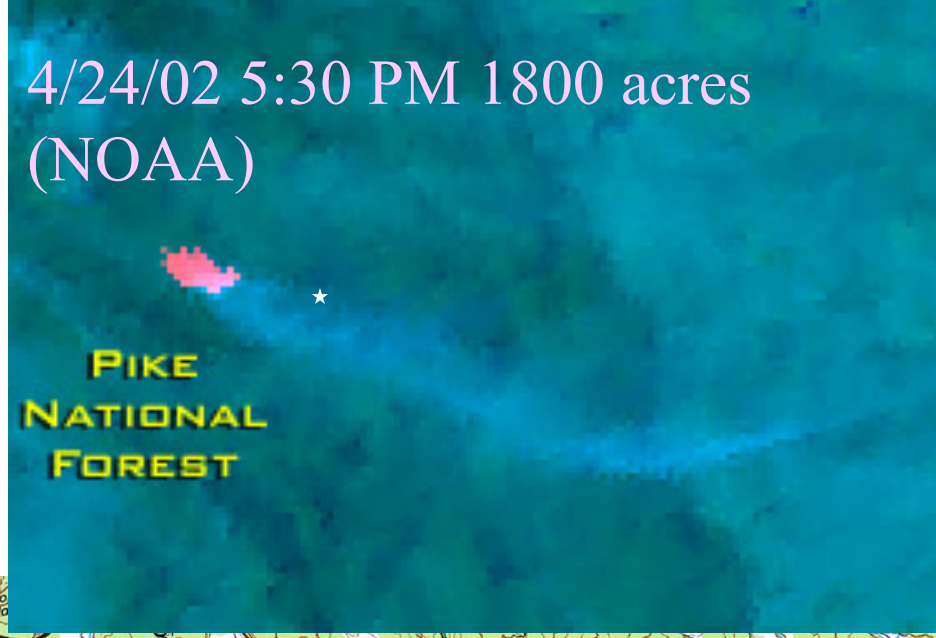
Started by lightning on 5/21/02 and quickly grew to 2000 acres. Houses 5 and 6 were both located 24 km north of the fire. Monitoring took place 5/22/02 to 5/23/02. Ultimately the fire consumed 3800 acres and cost 2.4 million dollars to fight

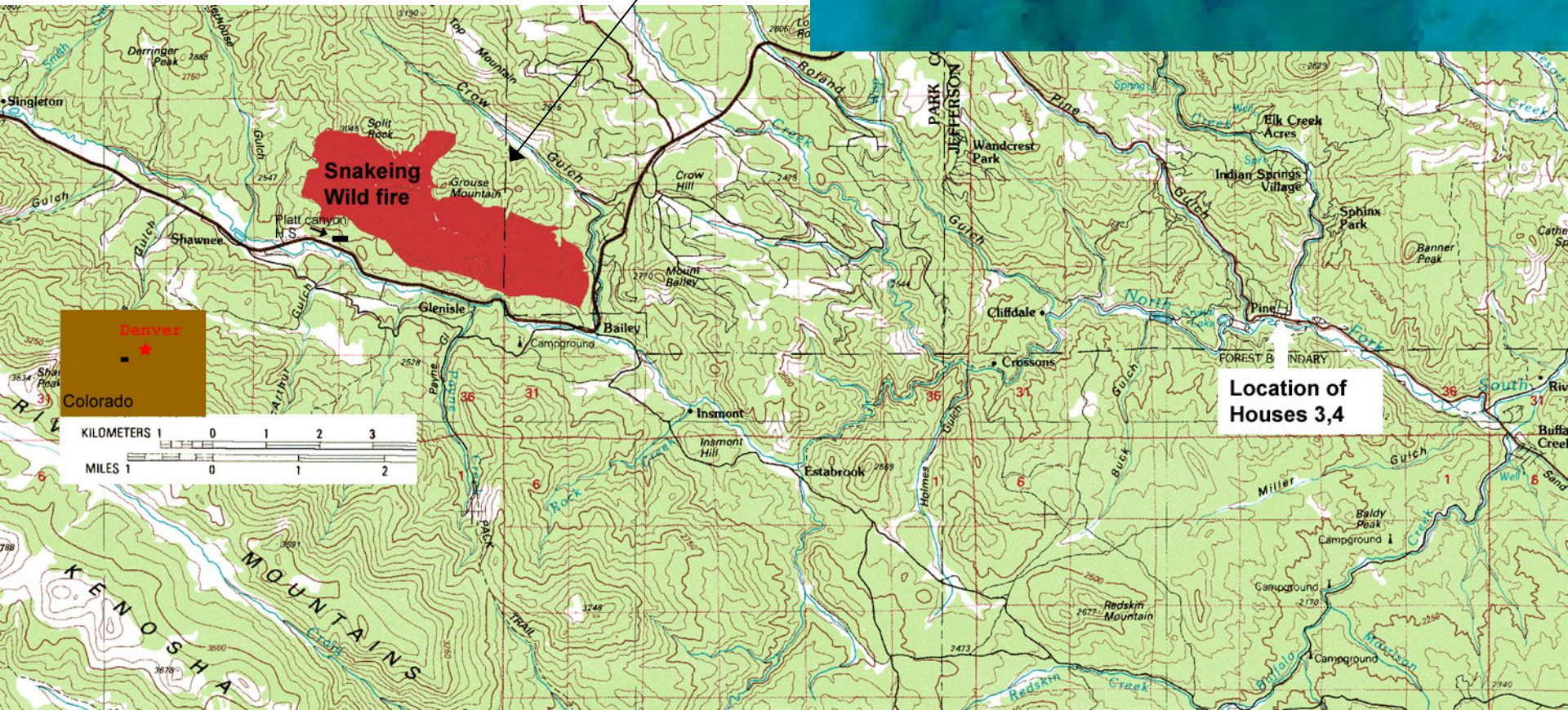




The Snaking wildfire

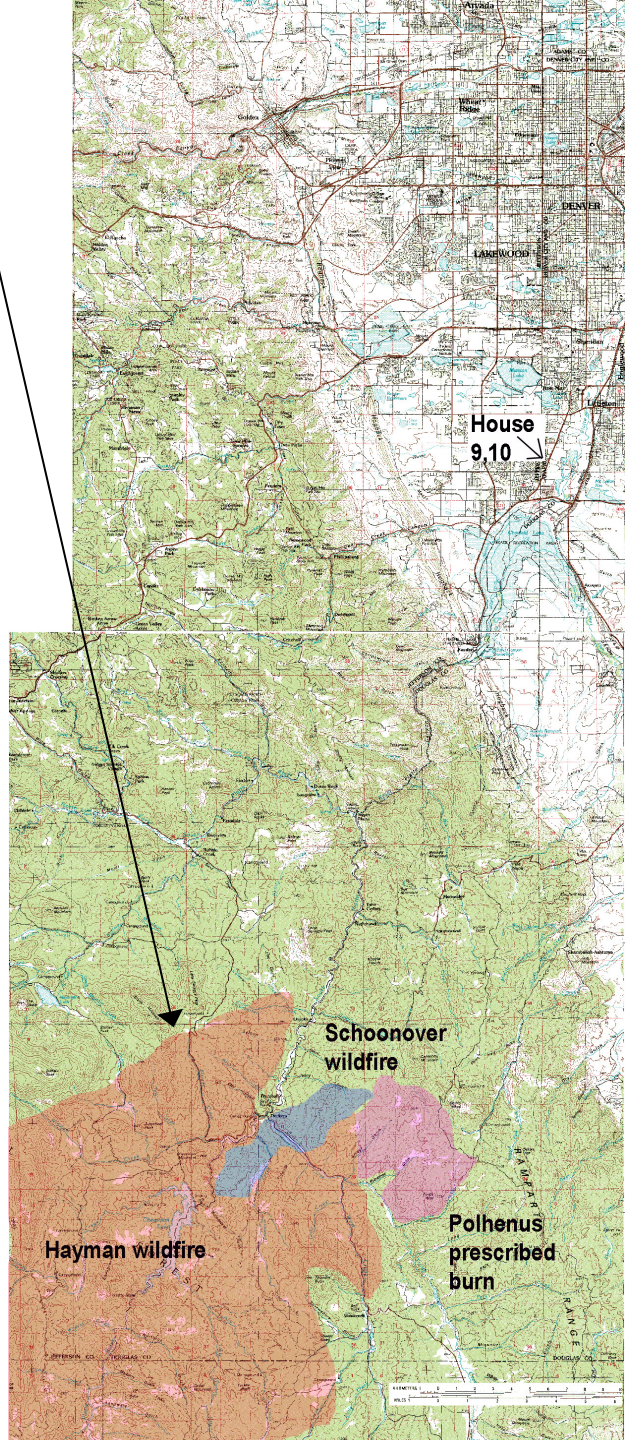
Began 4/23/02 behind Platt Canon High School. By 4/28/02 the fire consumed 2590 acres. Monitoring took place 4/25-4/26 11 km east of the fire

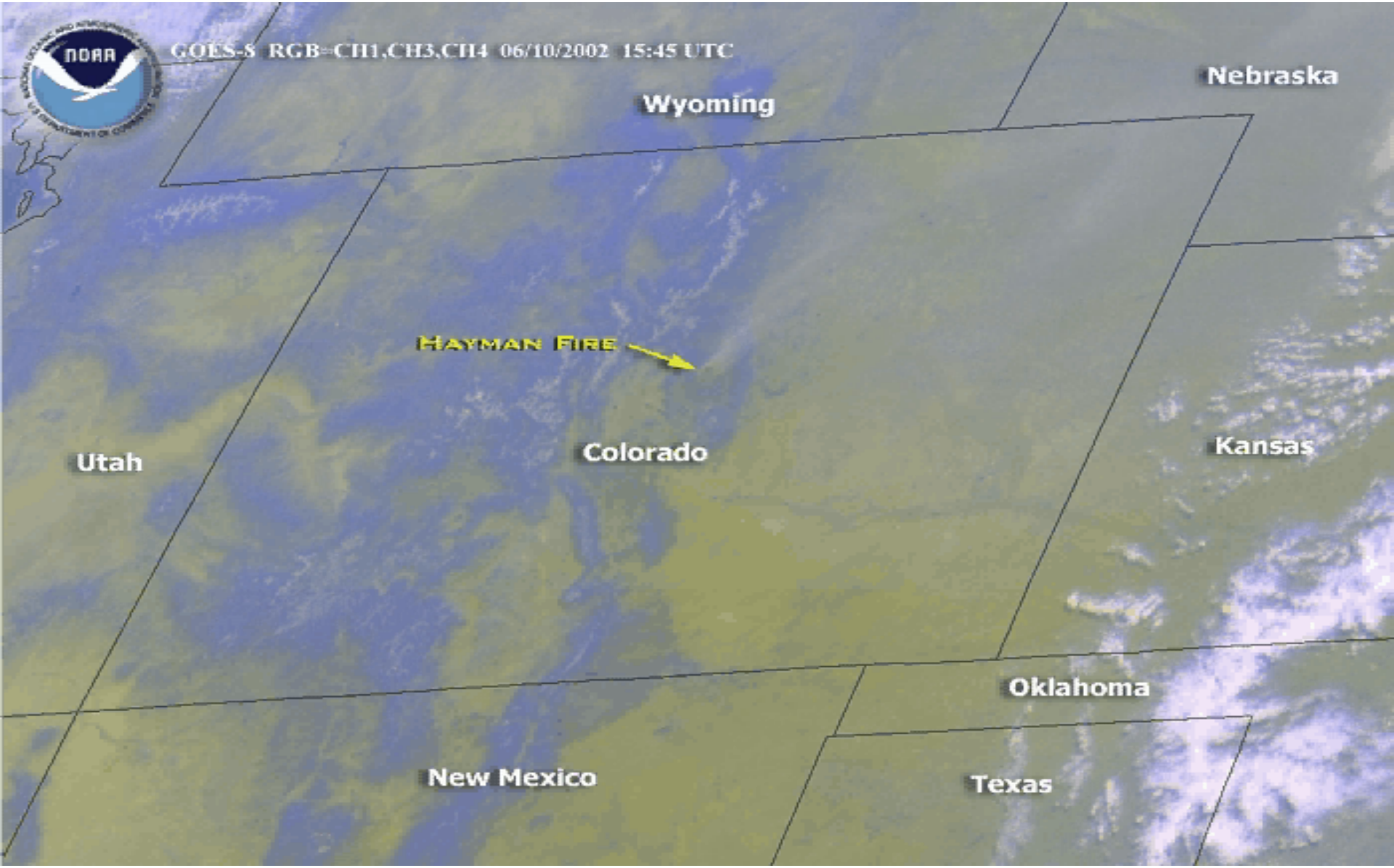




The Hayman Wildfire

- Began 6/8/02, contained 7/2/02
- Consumed 137,760 total acres (67,700 in first two days), 133 residences, 1 commercial building, 466 out-buildings
- Sampling during this fire was difficult because the smoke plume was energetic enough to rise to the upper atmosphere
- Sampling took place on 6/18/02. There had been smoke impact the previous day in Denver; similar atmospheric conditions were forecasted. Two houses were located in southern Denver located 47 km from the fire




GOES-8 RGB=CH1,CH3,CH4 06/10/2002 15:45 UTC
Wyoming
Nebraska
Hayman Fire
Utah
Colorado
Kansas
Oklahoma
New Mexico
Texas

Impact of Air Cleaners

House A has Air Cleaners
Compare to outside

House B has no Air Cleaners
Compare to outside

And compare to each other

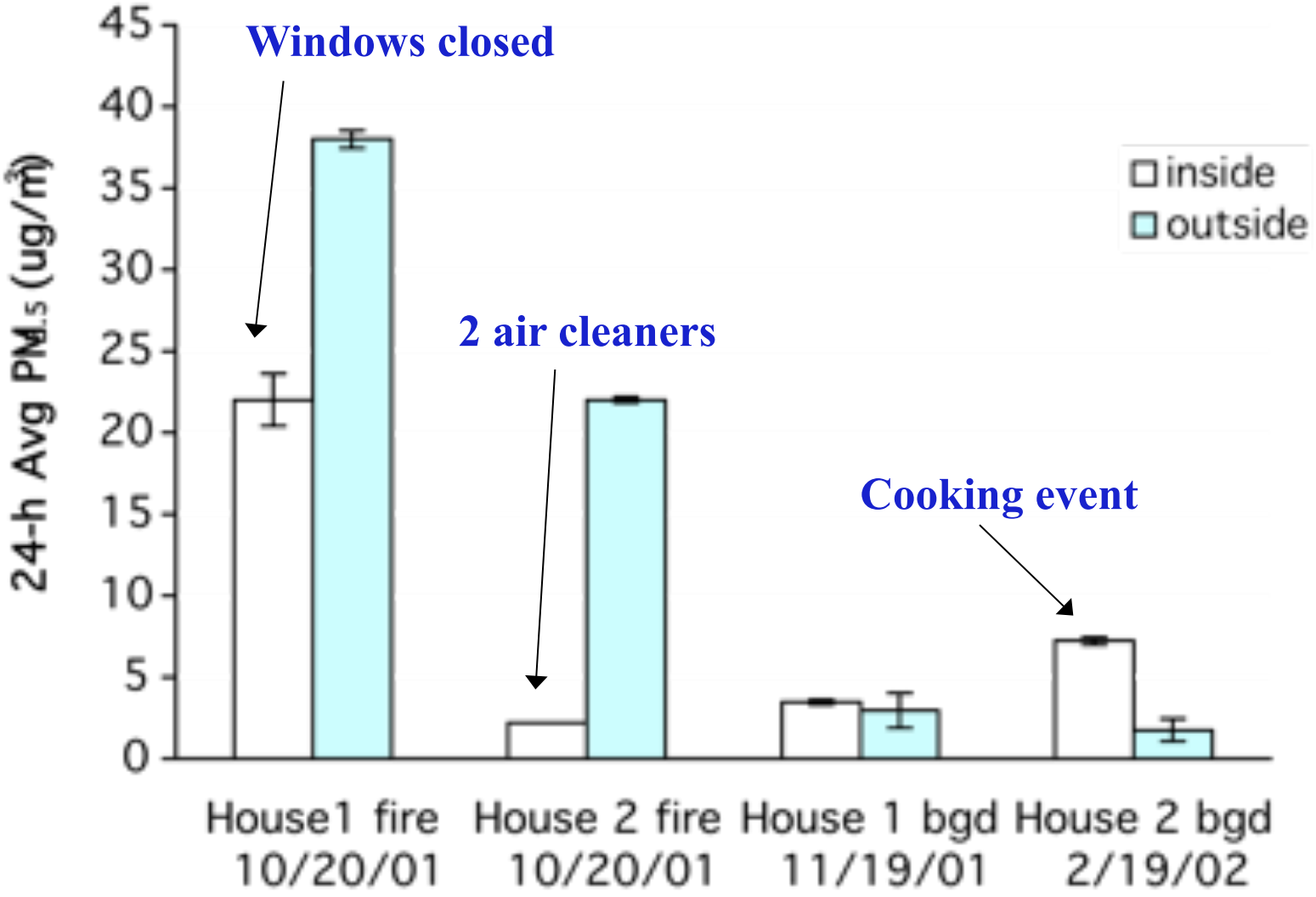
Impact of Windows Closed

House A during the Fire
Compare to outside

House A after Fire
Compare to outside

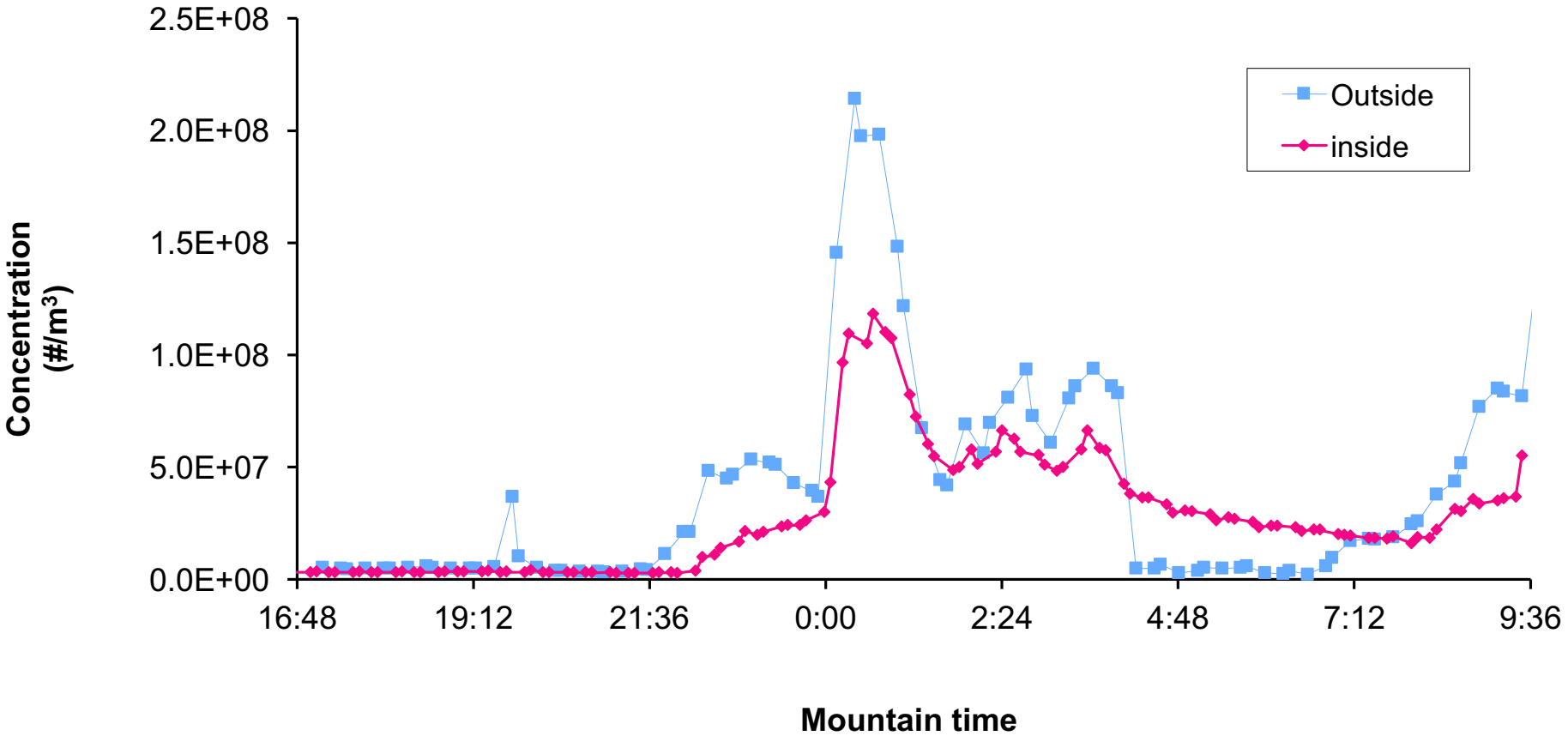
And compare to each other

Polhemus Prescribed Burn



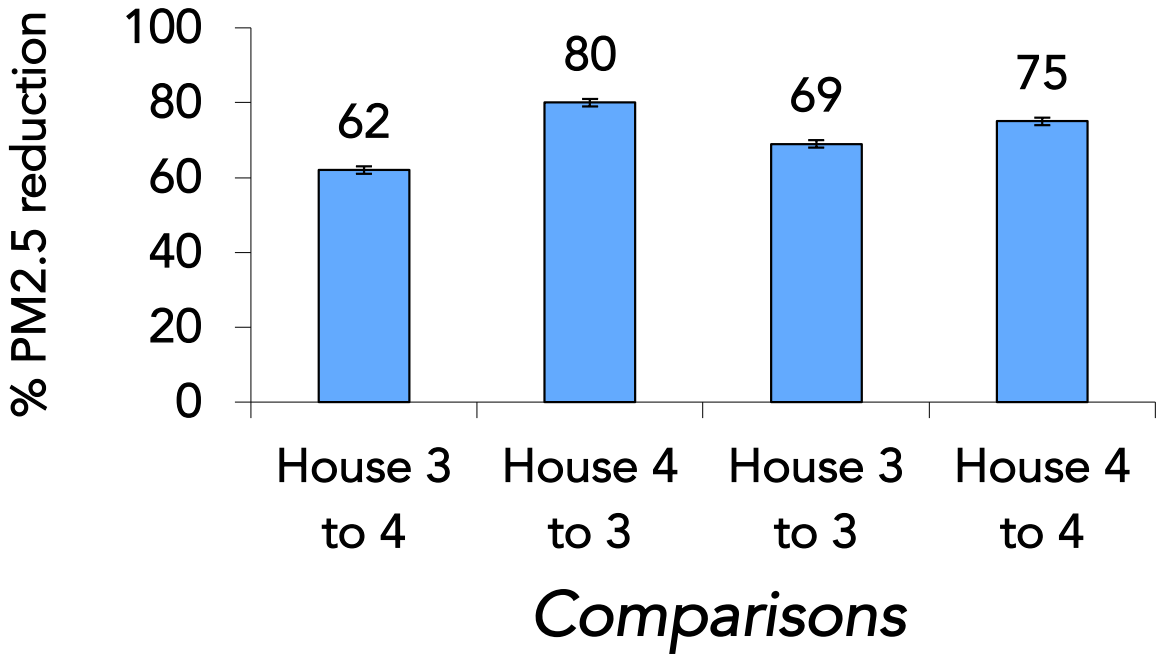
Polhemus Particle Counts

House 1 no air cleaner, number of particles 0.5-5.0 μm

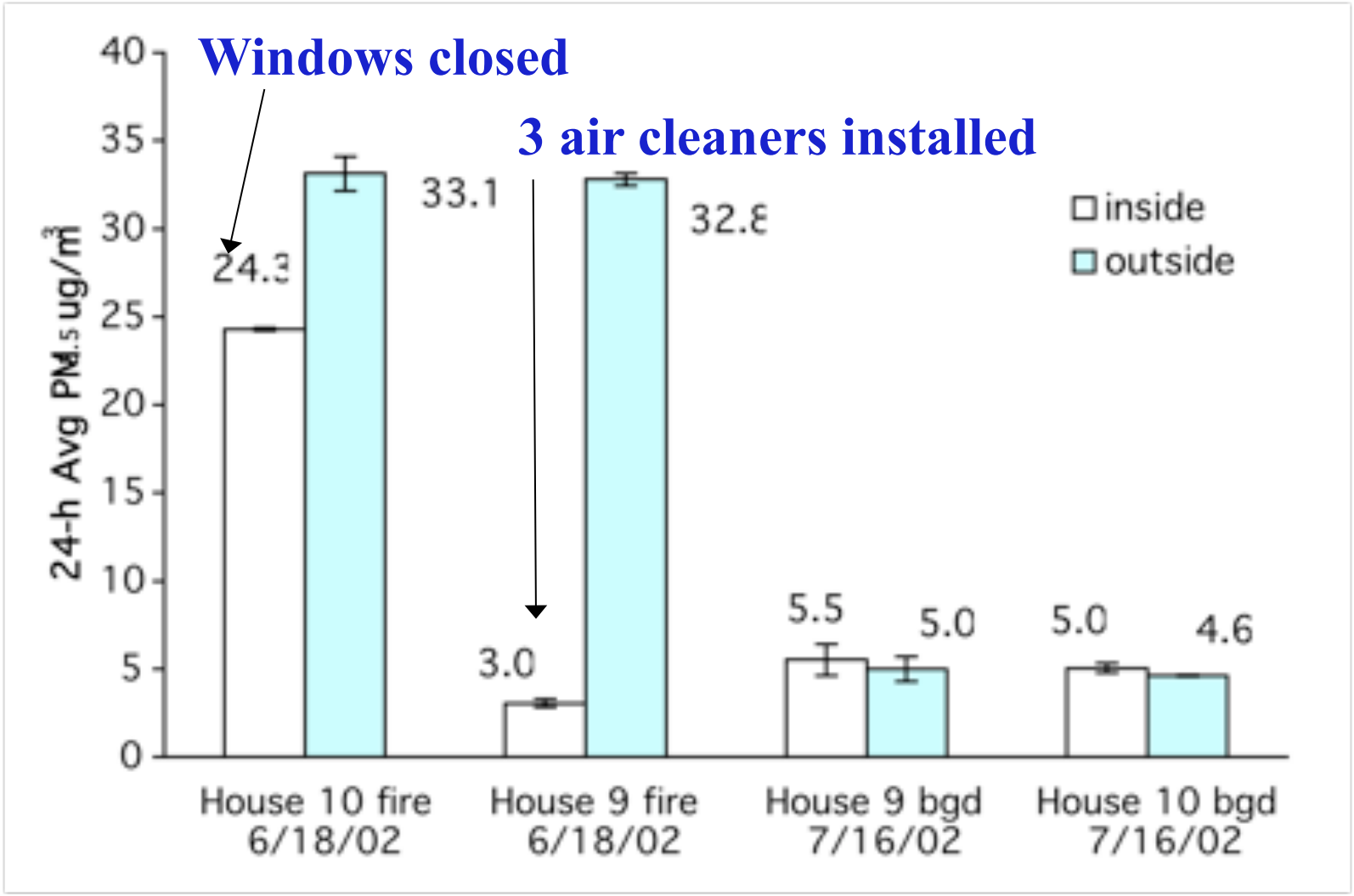


Snaking Wildfire

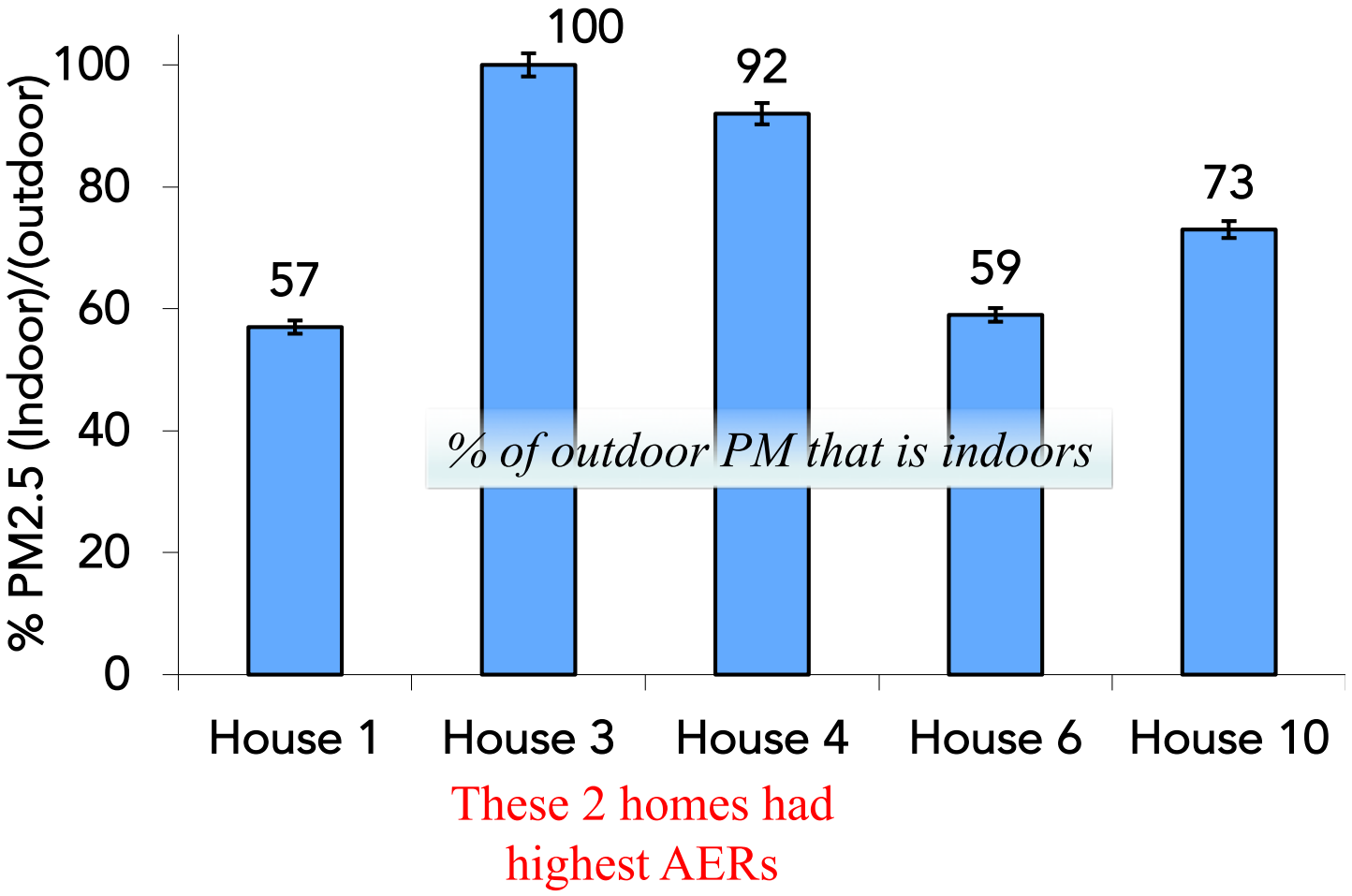
- Measurements were made on two consecutive days in houses 3 and 4, May 25 and 26 2002
- On May 25th air cleaners were installed in house 4
- On May 26th air cleaners were moved to house 3



Hayman Wildfire

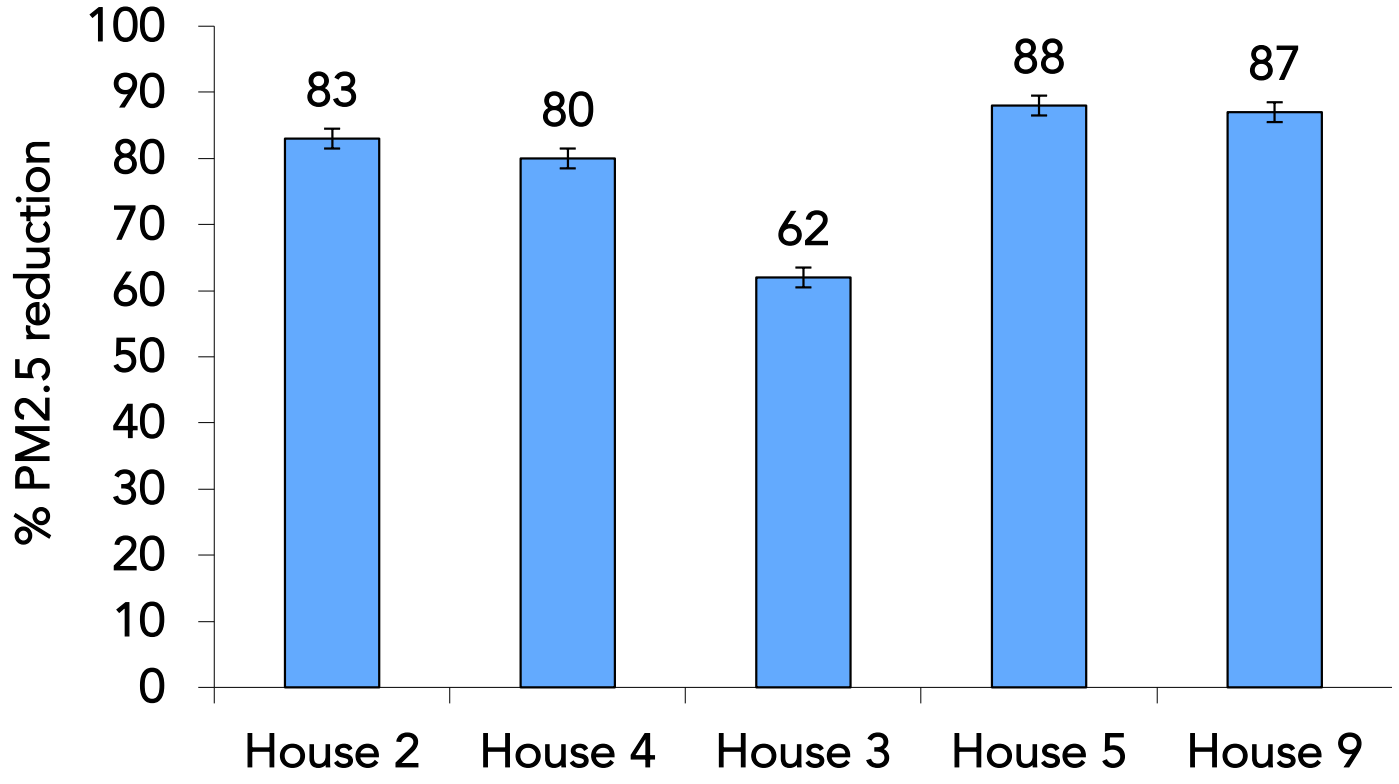


Indoor $PM_{2.5}$ is *elevated* during Fires in Homes without Air Cleaners

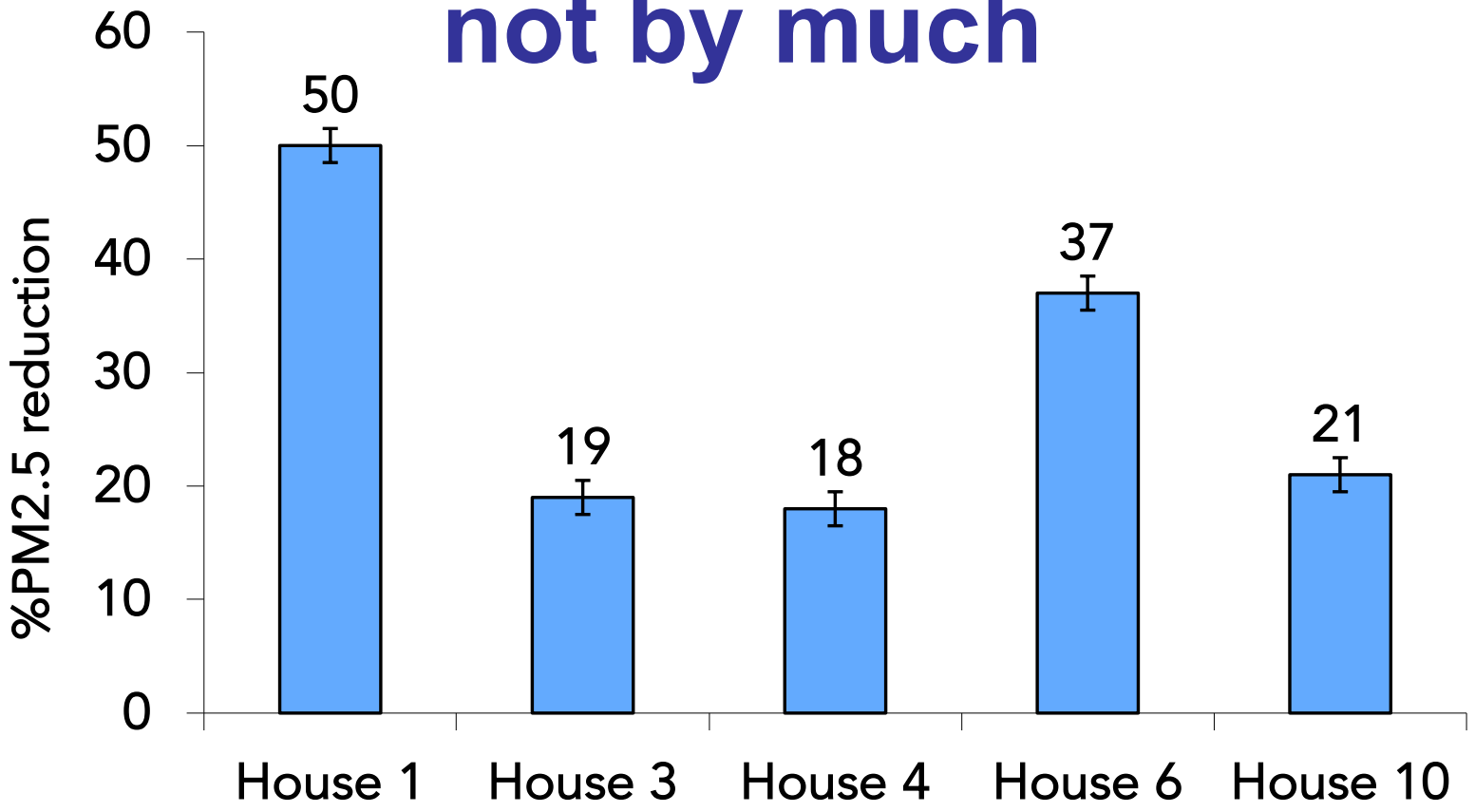


These 2 homes had highest AERs

Air Cleaners *Reduce* Indoor $PM_{2.5}$ during Fires



Keeping Windows Closed during Fires *does reduce* PM2.5 in Homes without Air Cleaners, but not by much



Summary

- Indoor $PM_{2.5}$ was elevated during fires
  - Indoor levels are 57%-100% of outdoor concentrations when windows are closed
- Air cleaners reduced indoor $PM_{2.5}$
  - by 62-88% when compared to homes without air cleaners
- Closed windows provided some protection
  - 18-50% reduction of indoor $PM_{2.5}$ when compared to background
- Indoor and outdoor background measurements were all similar
  - ranged between 3-5 $\mu g/m^3$

Acknowledgments

- US EPA Region 8
  - Funding
- US EPA Radiation and Indoor Environment Lab
- Tri-county Health Department
  - Sampling Equipment
- CDPHE
  - Gravimetric filter analysis
  - (Colleen Cambell) Information on weather, smoke movement, and access to volunteers
- Boulder Fire Department, US Forest Service
  - Data on wildfires, and access to volunteers


Thank You!

Impact of Air Cleaners

$$1 - \frac{\left(\frac{\text{Indoors AC } PM_{2.5}}{\text{Outdoors } PM_{2.5}}\right)_{\text{House A}}}{\left(\frac{\text{Indoors } PM_{2.5}}{\text{Outdoors } PM_{2.5}}\right)_{\text{House B}}} = (\%\ PM_{2.5}\text{reduction from AC})_{\text{House A}}$$

House A has Air Cleaners

House B has no Air Cleaners

Impact of Windows Closed

$$1 - \frac{\left(\frac{\text{Indoors } PM_{2.5}}{\text{Outdoors } PM_{2.5}}\right)_{\text{Fire}}}{\left(\frac{\text{Indoors } PM_{2.5}}{\text{Outdoors } PM_{2.5}}\right)_{\text{Background}}} = (\%\ PM_{2.5}\text{reduction from windows closed})_{\text{Fire}}$$

House A during the Fire

House A after Fire